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6. AUTHORS
Rishi Raj

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7. PERFORMING ORGANIZATION NAMES AND ADDRESSES
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14. ABSTRACT
We have conducted in-situ X-ray diffraction experiments at the Advanced Photon Source at the Argonne National Laboratory to explore the occurrence of unusual phase transformation or changes in crystal structure that are induced by electrical fields. Two specific results have been obtained. In one case the (1 1 0) and the (1 1 1) peaks in titanium oxide strengthen, while the (2 1 1) peak weakens, under the electric field at elevated temperature. The changes in the peak intensities are immediate, but they fluctuate with time even though the electric field remains constant. These fluctuations are ascribed to a difference in the interaction of charged defects, which are induced by

15. SUBJECT TERMS
electric field, far from equilibrium, phase transformation

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a. REPORT	b. ABSTRACT	c. THIS PAGE			Rishi Raj
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Prescribed by ANSI Std. Z39.18

Report Title

Final Report: Unusual Phase Transformations in Ceramics and Related Materials Under the Influence of an Electric Field

ABSTRACT

We have conducted in-situ X-ray diffraction experiments at the Advanced Photon Source at the Argonne National Laboratory to explore the occurrence of unusual phase transformation or changes in crystal structure that are induced by electrical fields. Two specific results have been obtained. In one case the (1 1 0) and the (1 1 1) peaks in titanium oxide strengthen, while the (2 1 1) peak weakens, under the electric field at elevated temperature. The changes in the peak intensities are immediate, but they fluctuate with time even though the electric field remains constant. These fluctuations are ascribed to a difference in the interaction of charged defects, which are induced by the electric field, with different planes in rutile depending on the intrinsic charged state of the planes. In a second system the reaction between alumina and titania is shown to be remarkably enhanced by the electric field. Furthermore, aluminum-titanate is shown to form below the temperature given by the phase diagram, in support of the concept that electrical fields can produce phases that are far from equilibrium.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received		Paper
12/23/2015	1	S.K. Jha, J.M. Lebrun, R. Raj. Phase transformation in the alumina–titania system during flash sintering experiments, Journal of the European Ceramic Society, (02 2016): 0. doi: 10.1016/j.jeurceramsoc.2015.10.006
12/23/2015	2	S.K. Jha, J.M. Lebrun, K.C. Seymour, W.M. Kriven, R. Raj. Electric field induced texture in titania during experiments related to flash sintering, Journal of the European Ceramic Society, (01 2016): 0. doi: 10.1016/j.jeurceramsoc.2015.09.002
TOTAL:	**2**	

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received	Paper
TOTAL:	

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Number of Presentations: 0.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received	Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Elected as a Distinguished Life Member of the American Ceramic Society, 2015.

Graduate Students

NAME	PERCENT_SUPPORTED	Discipline
Shikhar Jha	0.50	
FTE Equivalent:	**0.50**	
Total Number:	**1**	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Kiran Naik	0.50
FTE Equivalent:	**0.50**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Rishi Raj	0.05	
FTE Equivalent:	**0.05**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Shikhar Jha
Total Number: 1

Names of other research staff

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

The objective of this seed grant was to investigate whether unusual phase transformations can occur in ceramics under electric fields at elevated temperature. These experiments have come to be known under the general name of “flash sintering”. However, the purpose here was to see if phase changes can occur under similar circumstances in pre-sintered specimens. We have been able to demonstrate that indeed unusual phase changes take place that are far from equilibrium under flash conditions. In titanium oxide, the crystal structure as measured by the X-ray diffraction peaks during in-situ experiments at the APS synchrotron we see changes that appear and then vanish when the electric field is turned on and off. In the case of the alumina-titanium dioxide system, aluminum titanate is seen to from at temperatures below the equibrium temperature given by the phase diagram. The reaction between alumina and titania to from the titanate spinel is accelerated several fold under the electric fields. These results demonstrate the promise of using electric fields to form materials that cannot be form by conventional methods and phase equilibria.

Technology Transfer

Visited ARL in December 2014 to present a seminar and develop interactions. Host, Dr. Raymond Brennan.